Progress of MDI

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CEPC-SPPC Software Workshop
2016-8-29

Outline

- Tasks of MDI
  - IR lattice and layout design
  - Final Focusing magnets
  - Luminosity Measurement
  - Beam Induced Background Estimation
  - Detector shielding and radiation protection
  - Mechanics and integration
- Regular group meetings
  - Indico: http://indico.ihep.ac.cn/category/323/
  - Twiki: cepc.ihep.ac.cn/~cepc/cepc_twiki/index.php/Machine_Detector_Interface

Sources of Beam induced Background

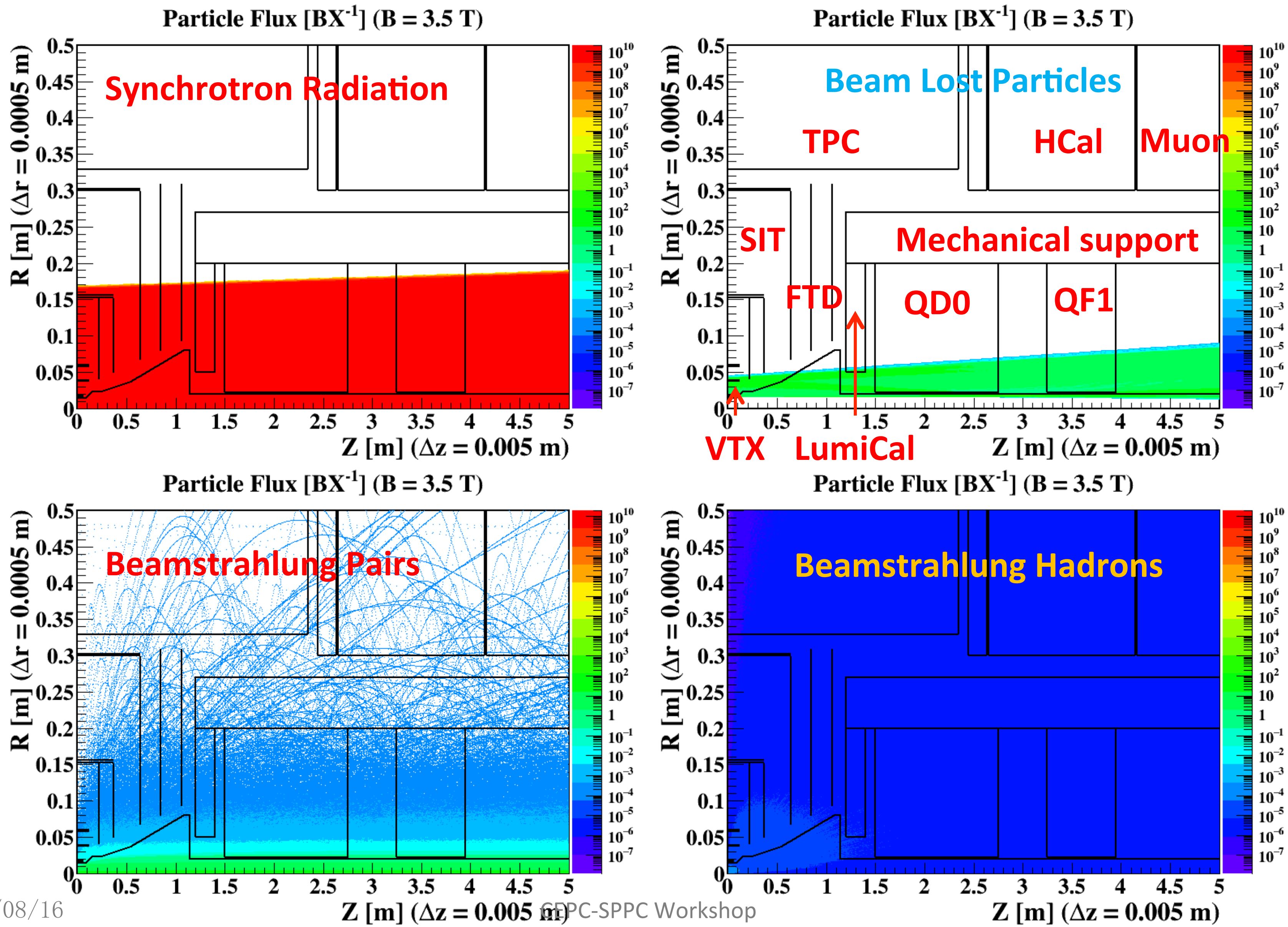
- Synchrotron radiation
  - – Bending magnet, Quadrupoles
  - – BDSIM (Geant4)
- Beam lost particles
  - – Radiative Bhabha, Beam gas scattering
  - – BBBrem … → SAD
- Beamstrahlung
  - – Electron positron pairs, Hadrons
  - – Guineapig++, Pythia6

Generator Information

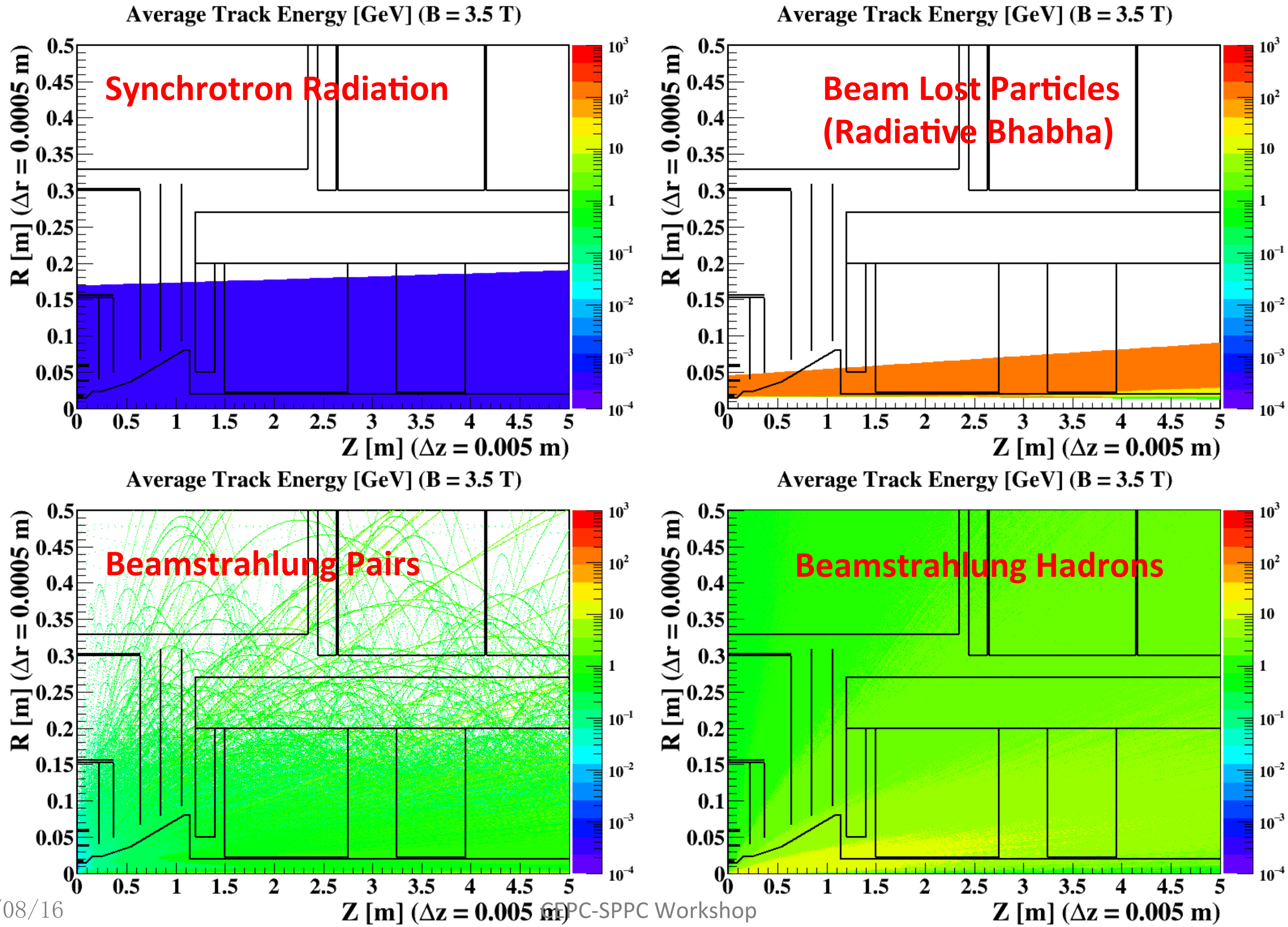
Generator	Simulated Process	Physical Cut
BDSIM (Geant4)	Synchrotron radiation	Classical electrodynamics; Photon Energy > 1keV
BBBrem	Radiative Bhabah	Photon Energy > 2% of beam energy; Simulate very small scattering angle
SAD	Transport in accelerator	Beam pipe radius
GuineaPig++	Beamstrahlung	Pairs: energy > 5 MeV; Hadrons: Standard QCD physics in Pythia
Pythia6	$\gamma\gamma \rightarrow Hadrons$	Standard QCD physics: Ecm>2GeV, MSTP(14)=10

- The generated background samples covered the acceptance of the detector

Particle Flux in the Same Scale



Average Energy of Tracks



Properties of Beam Induced Background

- Most beam induced particles have very forward momentum
- The **particle flux** of **synchrotron radiation** is the highest
- The **energy** of the **beam lost particle** is the largest and similar with the beam energy
- The **transverse momentum** of **hadrons from beamstrahlung** is the largest
- The flux of background is influenced by the **solenoid field**
- Current study priority: **synchrotron radiation > beam lost particle > beamstrahlung**

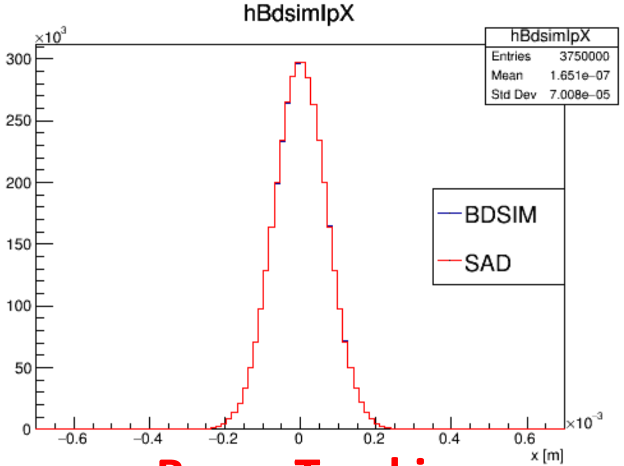
Tools for Synchrotron Radiation Study

- Mike Sulivan's code
  - Photon flux is calculated with geometry method.
  - Need other program to generate photon samples and simulate the interaction.
  - No detailed documents and manuals
  - Geometry definition is not convenient
  - Developed in Fortran. Further development is difficult for younger people.
- Decide to develop a new tool for synchrotron radiation study

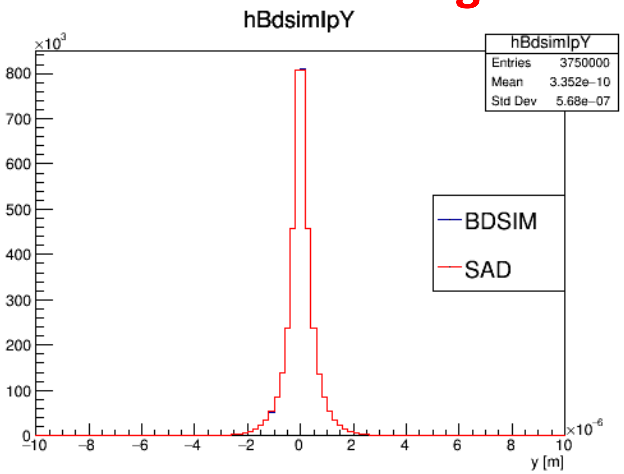
New Method to Simulate Synchrotron

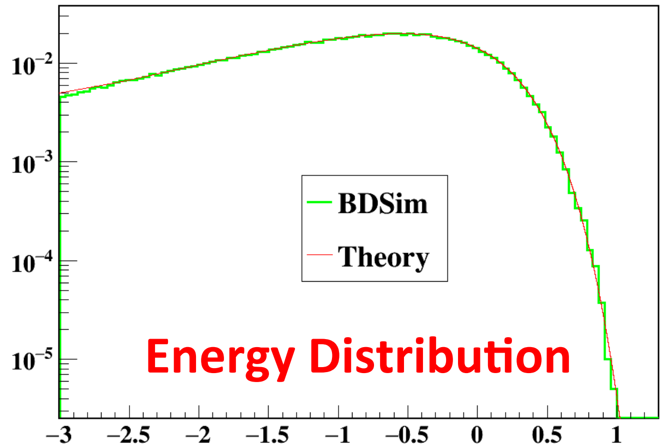
- Core idea
  - Track charged particles in magnetic field and generate synchrotron photons
- The synchrotron radiation process has be implemented in Geant4.
- A convenient way to model the element and magnetic field of accelerator.
  - BDSIM: A particle tracking code for accelerator based on Geant4
  - Simulate the material and field of accelerator automatically by reading the lattice file.
- Developed new functions to extract synchrotron information from each step of Geant4

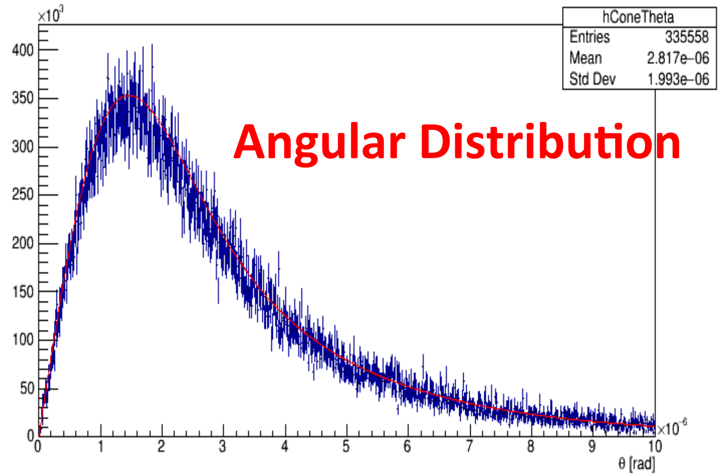
Validation of the New Method



Beam Tracking

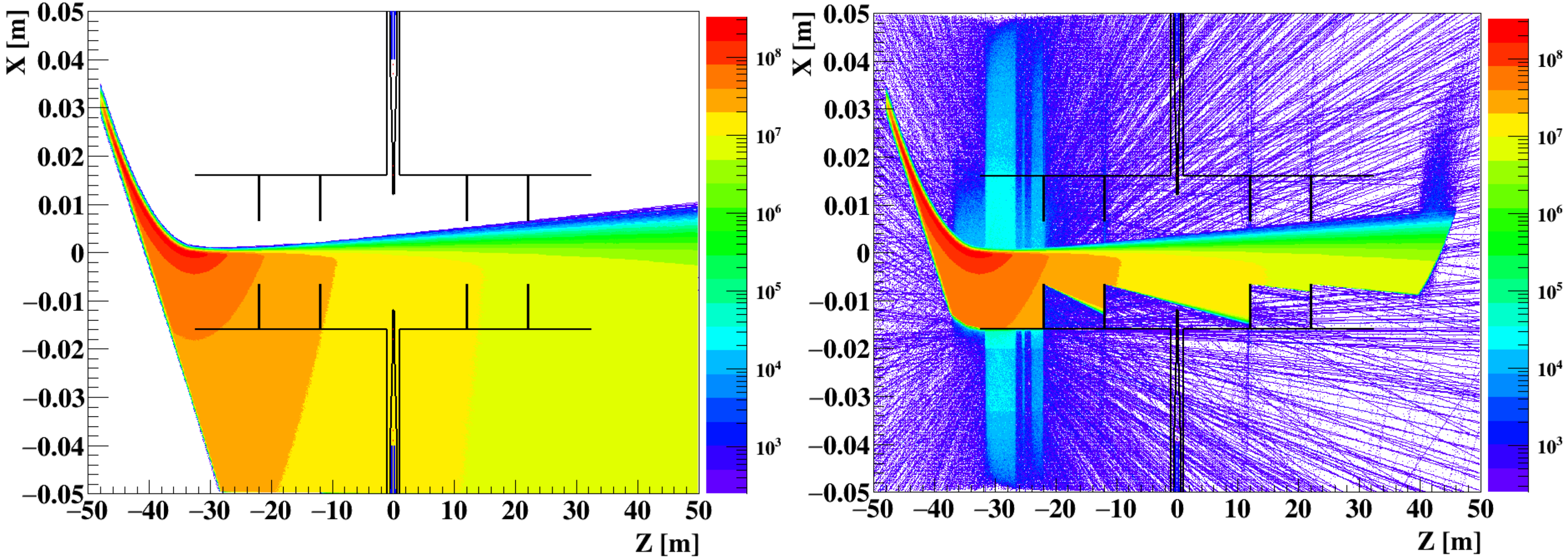






- The results of BDSim are compared with theory and other standard code. The results are consistent with each other

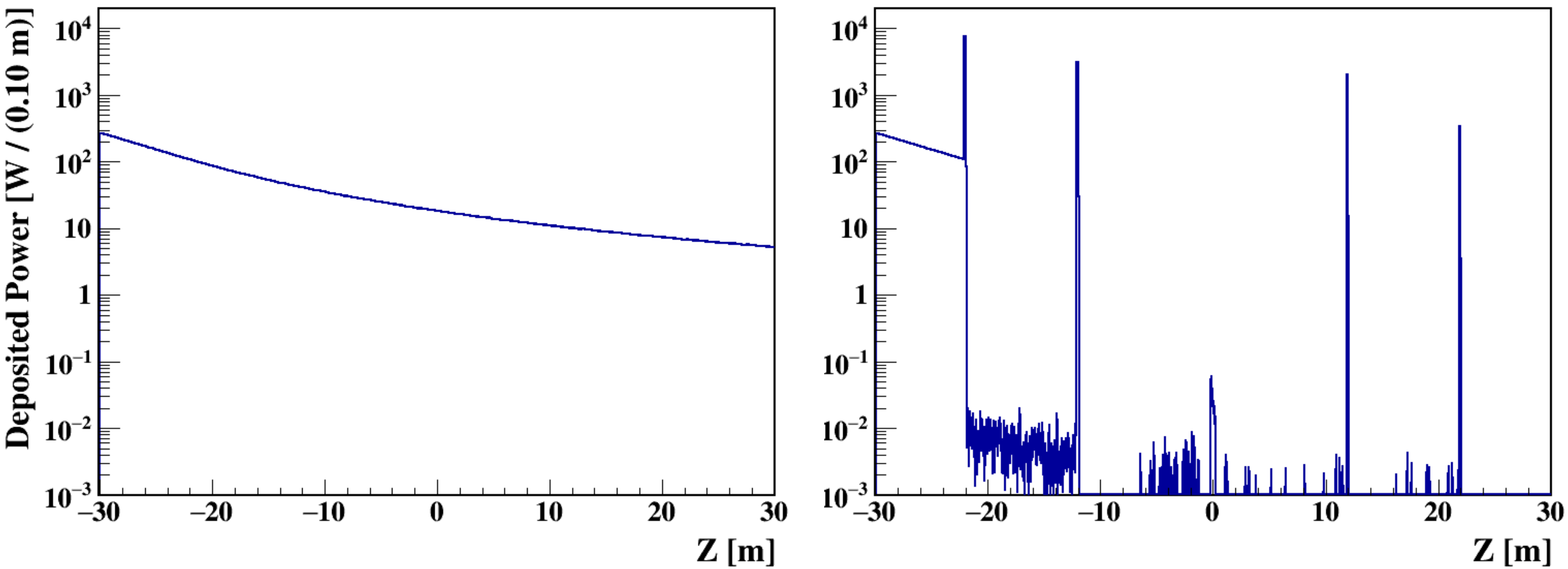
Synchrotron from Bending Magnets



Horizontal

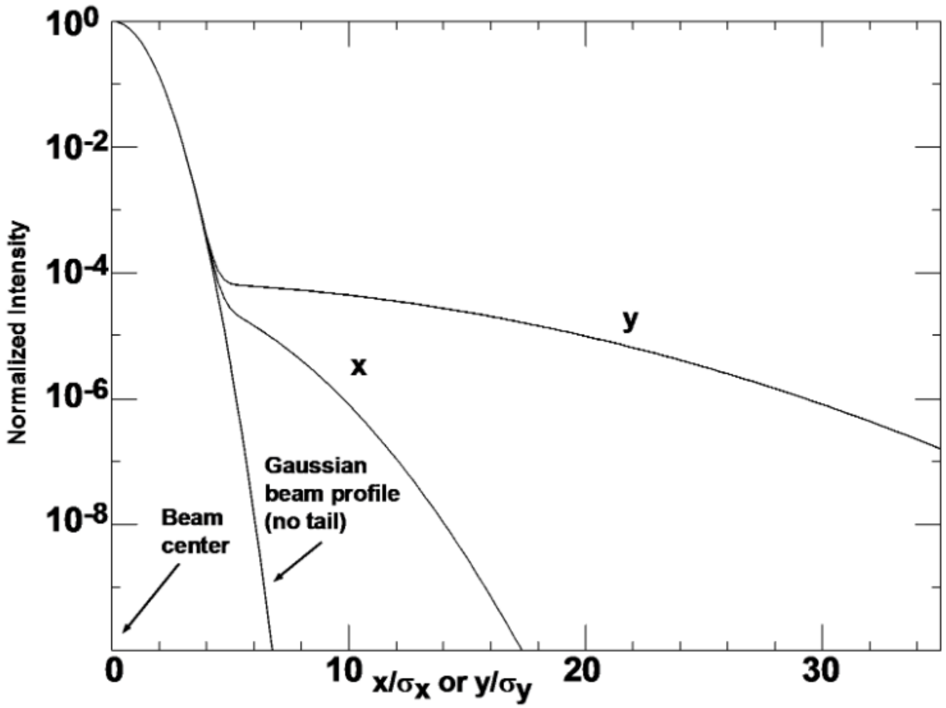
- In horizontal direction, synchrotron from bending magnets can be well suppressed by the collimators

Power of Synchrotron from Bending Magnet



- Power deposited at IP is about 25 W / (10cm) without collimators
- Power deposited at collimators are about 10 kW

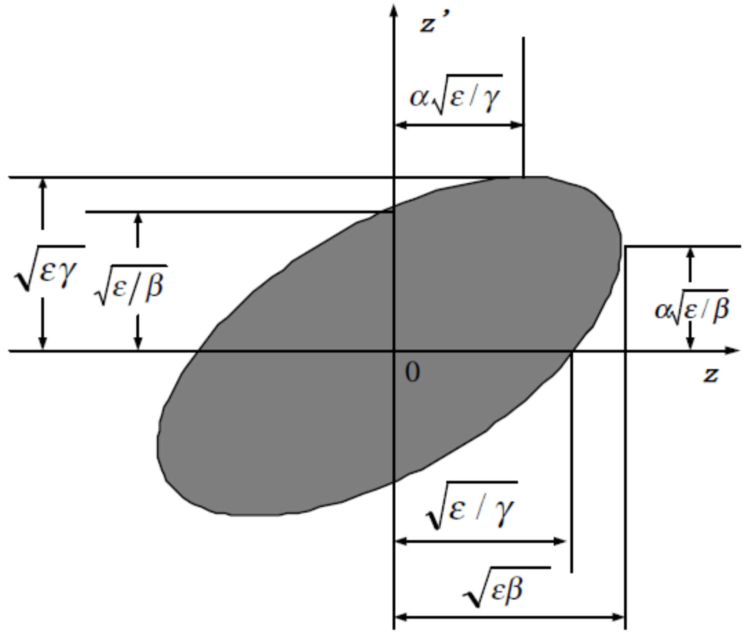
Synchrotron from Quadrupoles



- Synchrotron from quadrupoles are mainly caused by the beam halo
- Use a double Gaussian distribution to describe the beam distribution
  - Narrow Gaussian for beam core
  - Wide Gaussian for beam halo
  - $\sigma_x^{halo} = 3.4\sigma_x^{core}$; $\sigma_y^{halo} = 10\sigma_y^{core}$ (Round halo)
  - Fraction of beam halo: assumed to be 0.5%

Momentum Distribution of Beam Particles

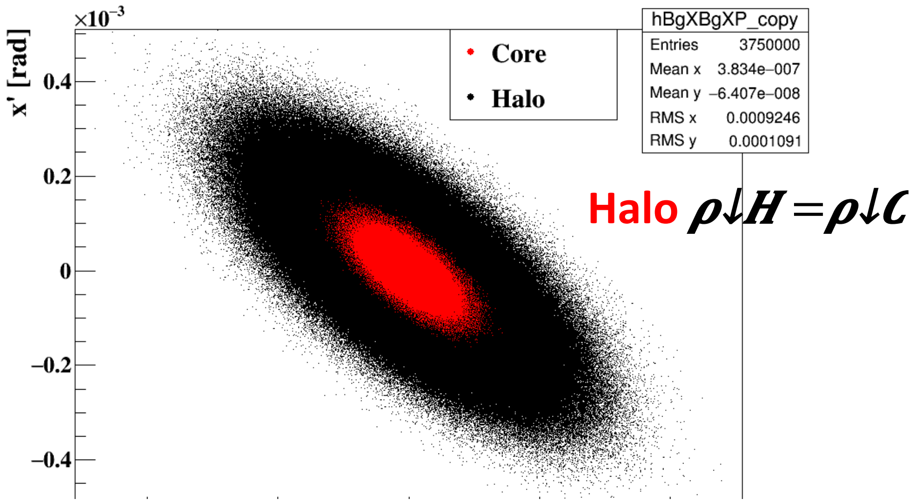
- Twiss parameters
  - $\alpha = -1/2\, d\beta(s)/ds$
  - $\gamma = 1+\alpha^2/\beta$
- $\sigma_x = \sqrt{\varepsilon\beta}$
- $\sigma_{x'} = \sqrt{\varepsilon\gamma}$
- When $\alpha \neq 0$, x and x' are correlated in phase space
  - $\rho = -\alpha/\sqrt{1+\alpha^2}$

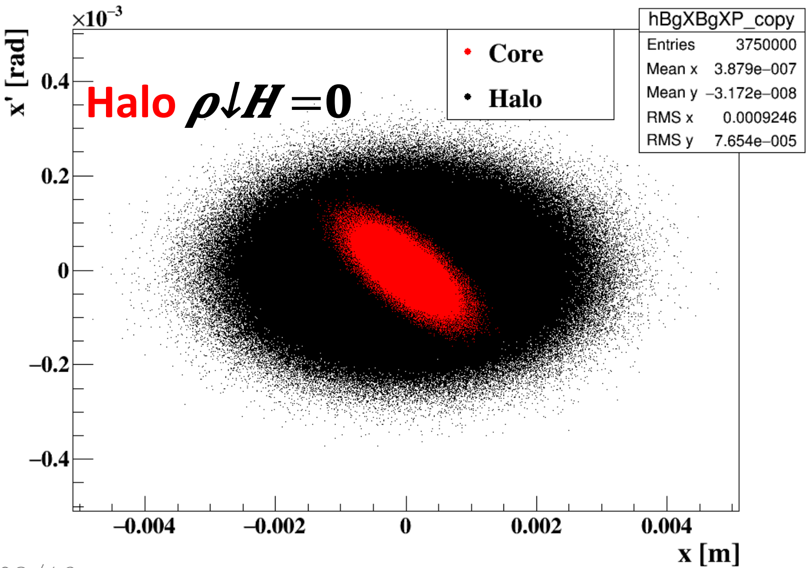


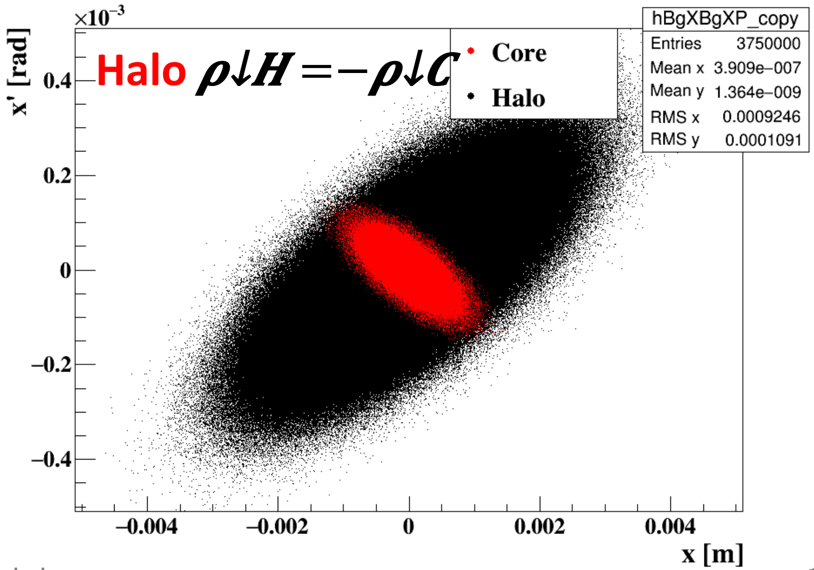
$$\gamma x^2 + 2\alpha x x' + \beta x'^2 = \varepsilon$$

Beam Halo in Phase Space

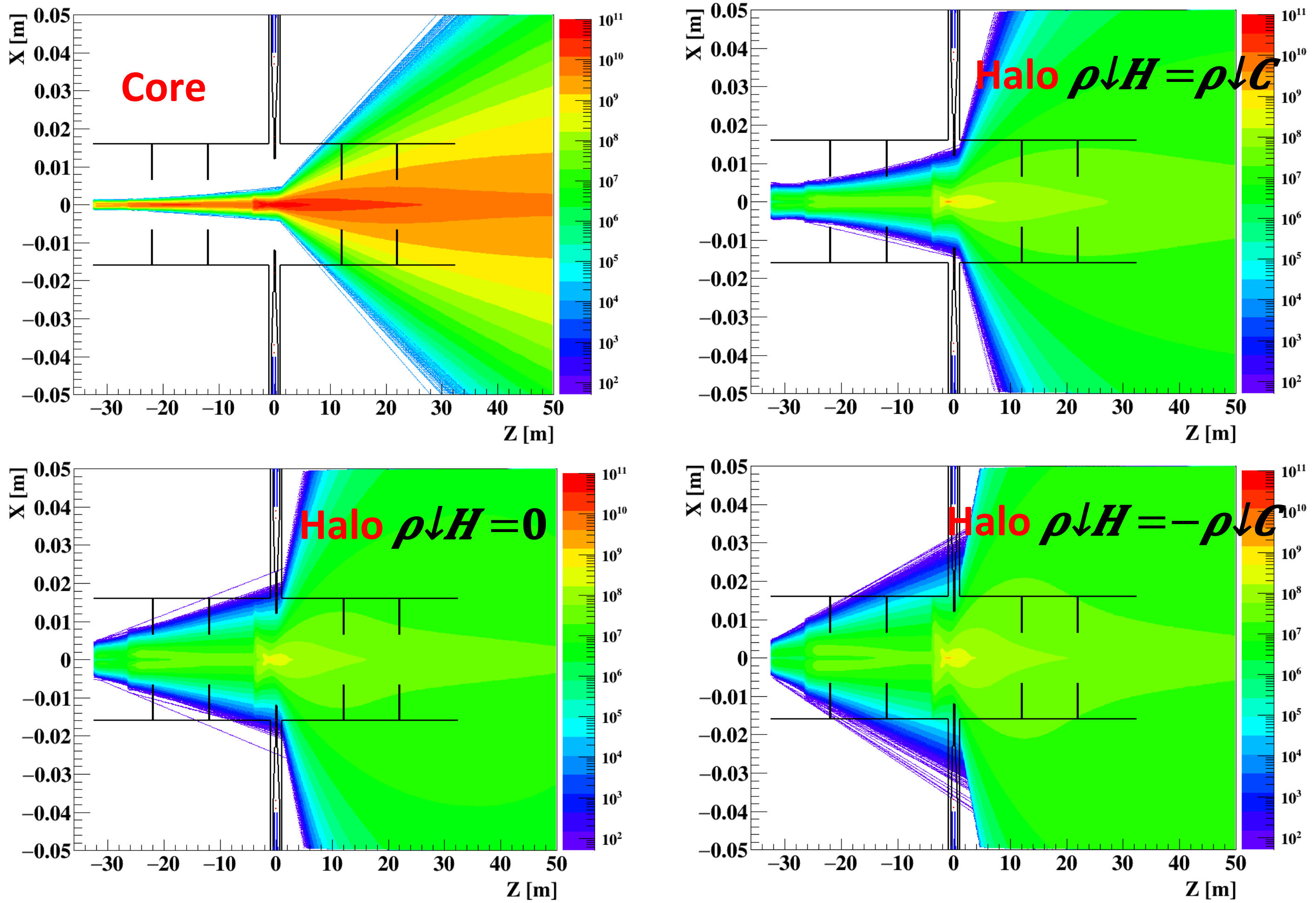
- Momentum distribution of beam particles are correlated with the position inside the bunch
- Try 3 correlation coefficient (>0, =0, <0) for halo particles





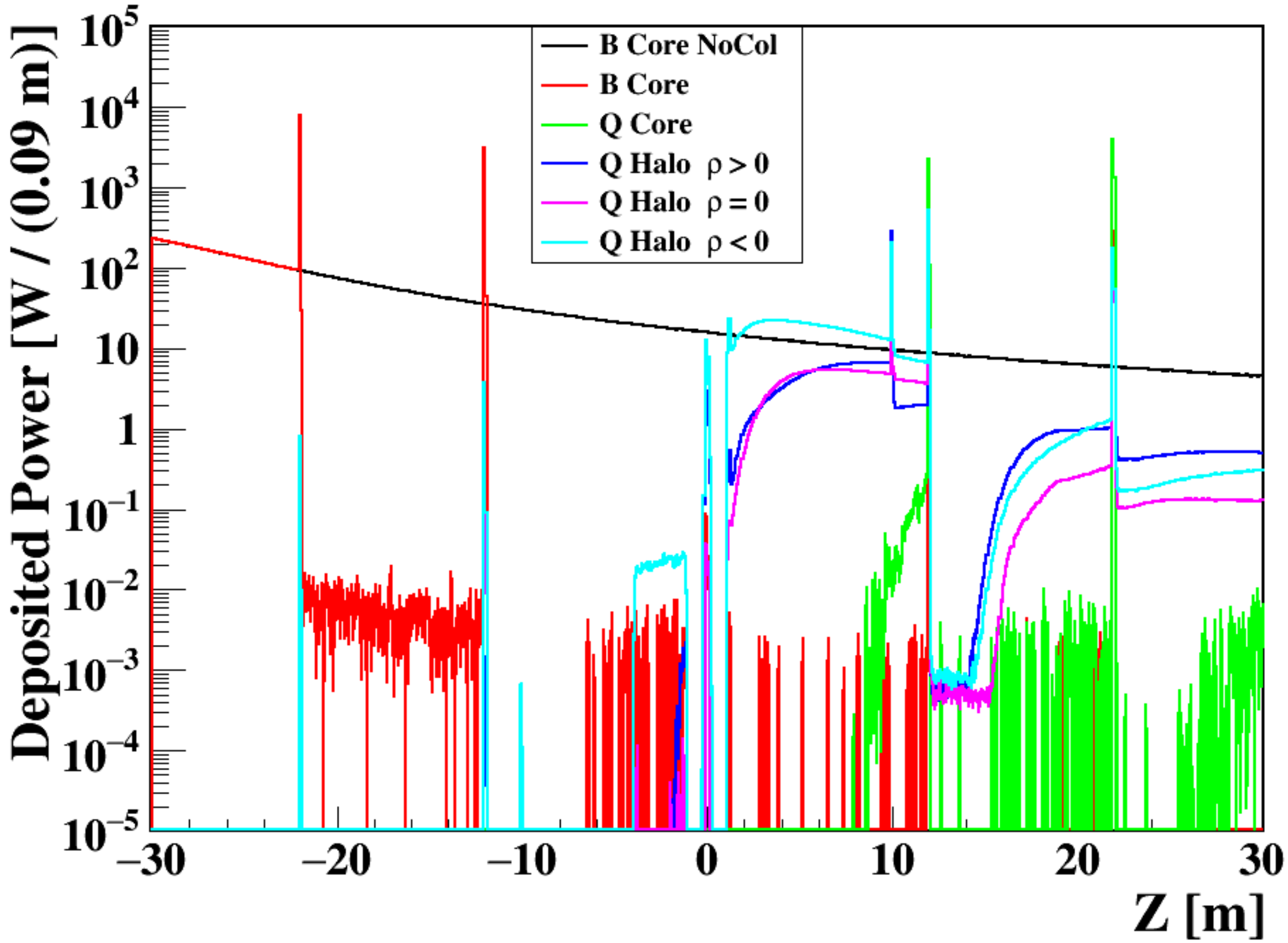


Flux of Synchrotron from Quadrupoles

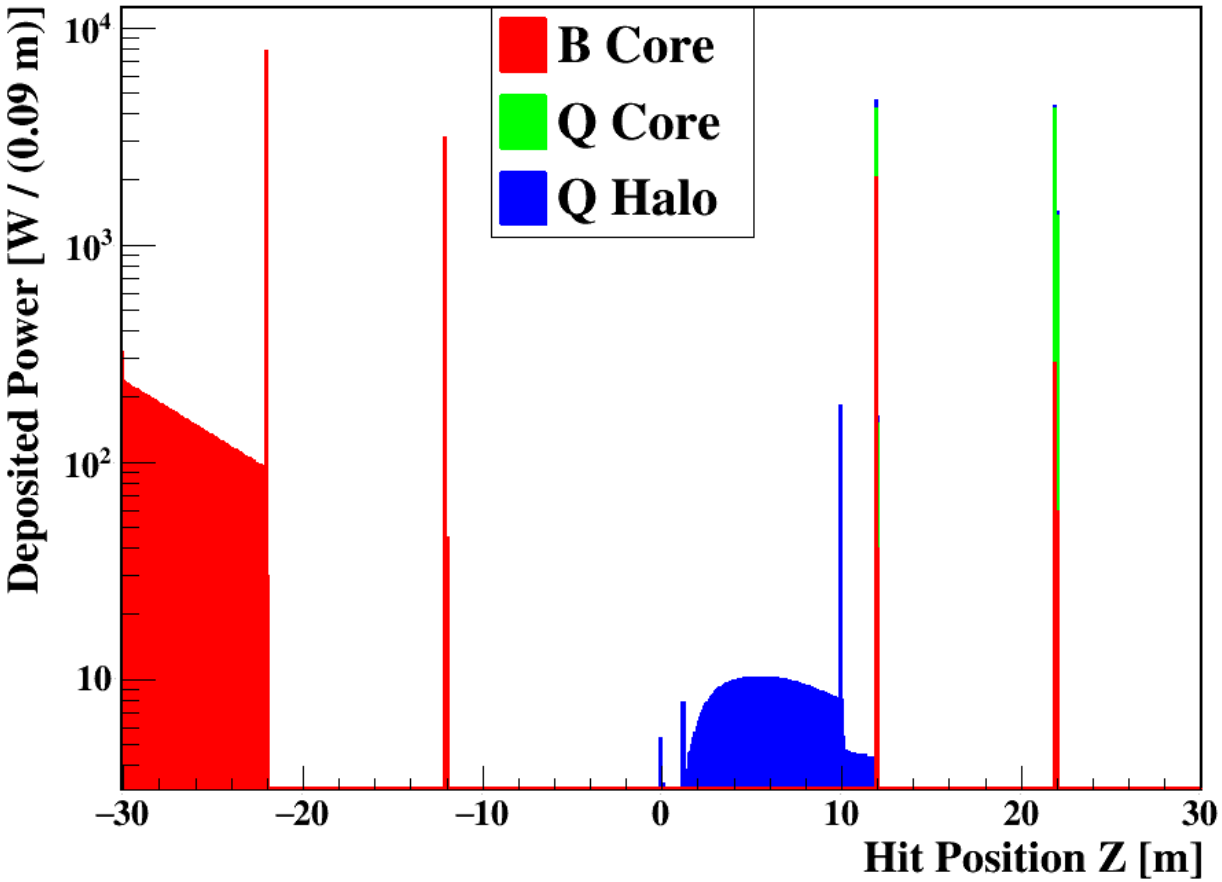


- The beam halo should be well suppressed to reduced photons from quadrupoles
  - Better vacuum, collimators ……

Power from Different Conditions



Total Power



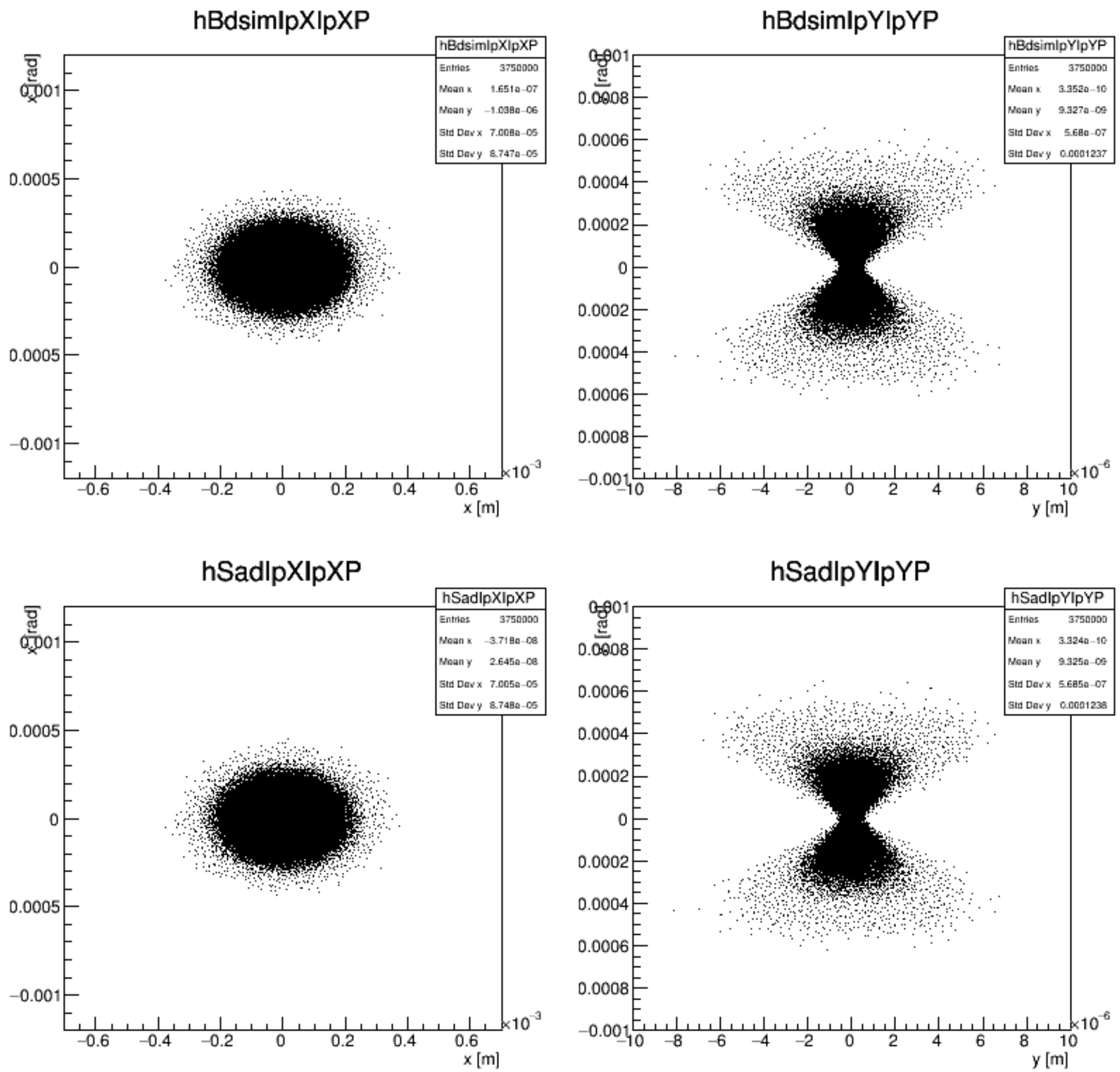
- The power from Halo is the average value of 3 cases

Conclusion

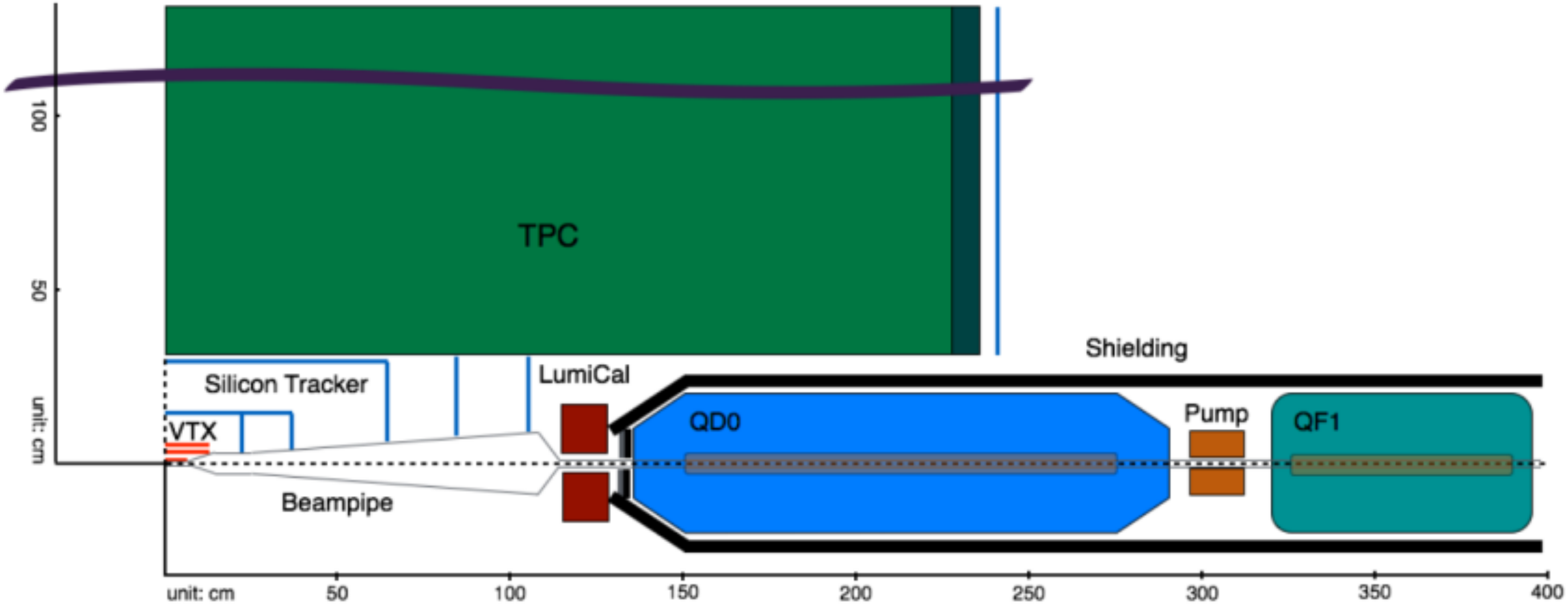
- Synchrotron Radiation might be the most important beam induced background at CEPC
- Developed a better tool to study the synchrotron radiation
- Synchrotron from bending magnets can be well suppressed by collimators
- Synchrotron from quadrupoles should be further suppressed in both accelerator and IR design
- Other backgrounds should also be kept on studying

Thank You

Backup

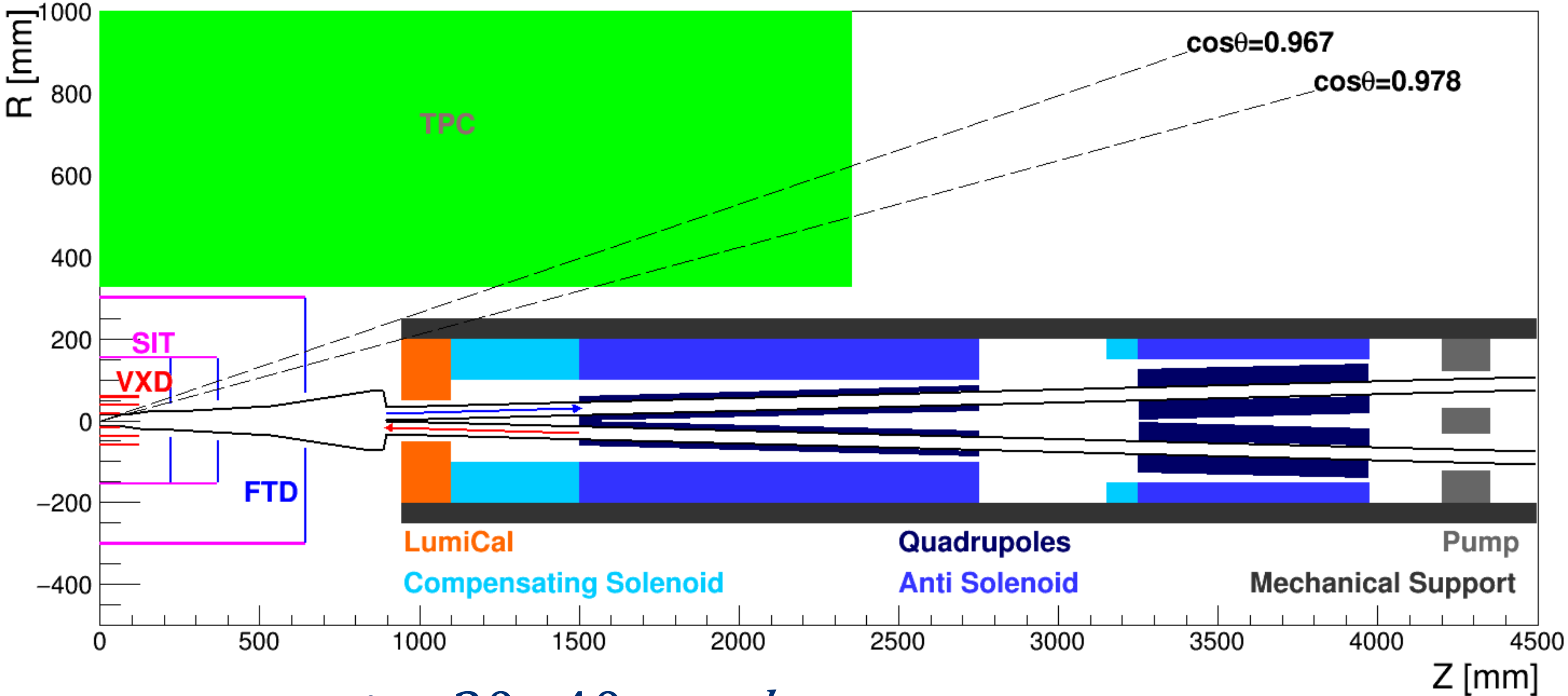

hBdsimIpXIpXP
hBdsimIpXIpXP
Entries 3750000
Mean x 1.651e-07
Mean y -1.038e-06
Std Dev x 7.008e-05
Std Dev y 8.747e-05
x [m]
hBdsimIpYIpYP
hBdsimIpYIpYP
Entries 3750000
Mean x 3.352e-10
Mean y 9.327e-09
Std Dev x 5.68e-07
Std Dev y 0.0001237
y [m]
hSadIpXIpXP
hSadIpXIpXP
Entries 3750000
Mean x -3.718e-08
Mean y 2.645e-08
Std Dev x 7.005e-05
Std Dev y 8.748e-05
x [m]
hSadIpYIpYP
hSadIpYIpYP
Entries 3750000
Mean x 3.324e-10
Mean y 9.325e-09
Std Dev x 5.685e-07
Std Dev y 0.0001238
y [m]

IR Layout -- Single Ring



- L* = 1.5m. To achieve higher luminosity, larger dynamic aperture.
- Many detailed problems are being considered based on this design.
  - Quadrupoles, anti-solenoid, compensating solenoid, luminosity measurement, shielding … …
- Level of beam induced background should be estimated to evaluate the design

IR Layout -- Partial Double Ring



- Crossing Angle = $30{\sim}40\,mrad$
- QD0: 200 T/m, L* = 1.5m (Space limitation)
- Compensating solenoid: 13T (Nb_3Sn), 0.4m ($\int B_z\, ds=0$)
- Some prototype study of magnets are in preparation
- Influence on the detector is under study